Workshop on Specialty Optical Fibers and their Applications

Hybrid silica and laser-dye-doped polymer fiber

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Abstract: We report the fabrication of a hybrid optical fiber with silica core and laser-dye-doped UV curable polymer cladding. Its potential to act as a combined intrinsic light source and FBG sensor is demonstrated.
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1. Introduction

Laser-dye-doped polymer optical fiber offers a low cost solution to provide fiber based broadband light source, which is useful in many polymer fiber based sensors [1]. However, the major limitation for using organic laser dyes is the low operating temperature (below 200 ^{o}C). Therefore they can only be doped in materials with low processing temperature such as PMMA, and not in the widely used optical fiber material, silica. Moreover, PMMA fiber came with an obvious disadvantage of having much higher propagation loss compared to that of a silica fiber. In view to overcome these problems, a hybrid fiber with silica core and dye-doped polymer cladding is proposed and demonstrated.

The hybrid fiber was fabricated on a standard silica fiber drawing tower. Dye-doped polymeric resin can be added to the coating die module on the tower, and cured by the tower's UV lamp during the draw of the silica core (<60 µm) from a standard preform. The cured polymer acts as the outer cladding of the fiber, at the same time, provides a protective layer for the thin silica core. The resultant double-clad hybrid fiber has an outer diameter of ~180 µm.

In this paper, a detailed fabrication method of the fiber is presented. The result of broadband fluorescence generated by using the side-illumination fiber bending method [2] is also presented. Moreover, Bragg grating is written into the silica core with the corresponding Bragg wavelength. Thus, the potential for the fiber to act as a combined intrinsic light source and Fibre Bragg Grating (FBG) based sensor is demonstrated.

2. Fabrication method

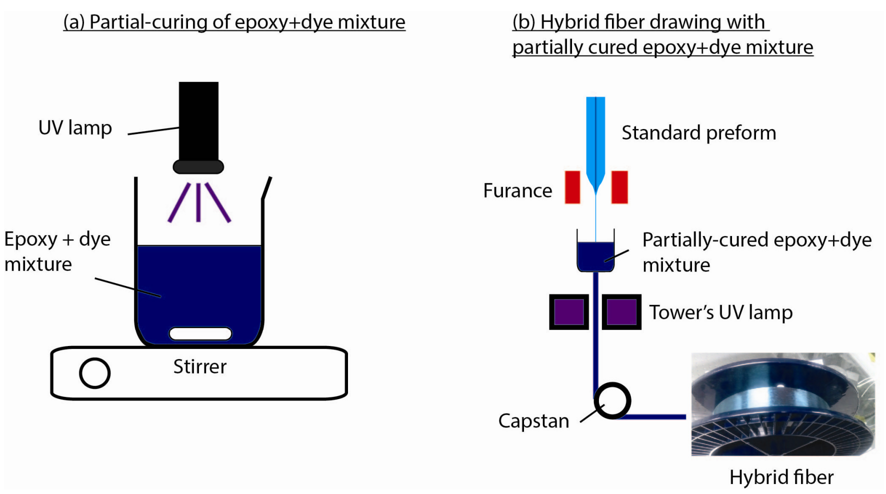

Fig. 1(a) Schematics to show the method for partial-curing of the UV curable epoxy and laser dye mixture to increase the viscosity, (b) Schematics to show drawing method of the hybrid fiber. Inset: Photo of drawn fiber on a reel

The fabrication of the hybrid fiber follows a 2-part procedure, illustrated in Fig.1. The first part of the procedure required a partial UV curing of the mixture of optical epoxy (EPO-TEK OG134 from Epoxy Technology) and laser dye (NB690 from Exiton) to increase the viscosity, illustrated in Fig. 1(a). The given refractive index of OG134 is <1.4230 at 589 nm. The total volume of the mixture was 40 ml, and the dye concentration was 600 ppm. A magnetic stirrer was used to mix the resin, while illuminated by a UV lamp (from UVATA) with power of 50W for 20 minutes. This process was necessary to ensure homogeneous fiber drawing during part two of the procedure, illustrated in Fig. 1(b).

The hybrid fiber was drawn on a standard silica fiber drawing tower (Nextrom OFC20). A Ge-doped silica core preform (Silitec) was drawn as the core part of the fiber with a diameter of 60 µm, with Ge-doped region of ~10 µm and Δn= 0.0038. A coating die with an aperture of 270 µm was used on the tower, which allowed a hybrid fiber with overall diameter of ~180 µm to be drawn. Note that the drawing speed and the tower's UV lamp (Fusion) power were chosen specifically so that homogeneous fiber can be drawn. Also, enabling the epoxy to be fully cured with minimal photobleaching [3] made to the laser dye.

3. Fiber Characterization by side pumping

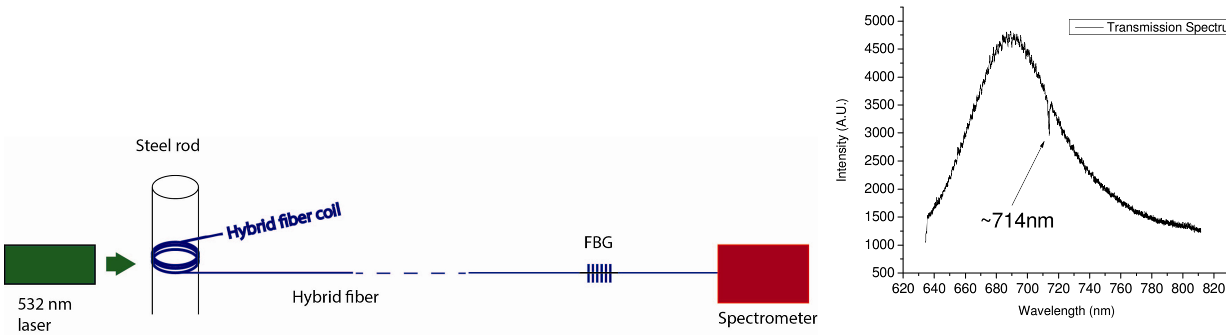

Fig. 2. Schematics to show the fiber bending side-illumination method used to characterize the fiber and FBG. Inset: Transmission fluorescence spectrum of the FBG written in the fiber.

The fiber was characterized by a bending side-illumination method described in [2]. An experiment was carried out to find the optimum bend radius and number of turns in the coil. It was found that bend radius of 1 mm with five turns in the coil facilitated the maximum amount of pump light coupled into the fiber. A cut-back loss measurement was made using this setup, and the propagation loss of the fiber was ~1.3 dB/m at the peak fluorescence wavelength, which was indeed better than that found in a dye-doped clad, all-polymer fiber reported previously with loss of >3 dB/m [2].

The fiber was hydrogen loaded, and a FBG was written into the fiber using the phase mask technique with a 190 nm ArF excimer laser. Total length of grating= 8 mm and total scanning time= 10 mins. A length of ~1 m of the hybrid fiber is used in the experiment. It was side-pumped by a 532 nm DPSS laser at 50 mW, and the end-facet was cleaved by a Vytran cleaver. The spectrum was taken by a UV-4000 Ocean Optics spectrometer. The transmission spectrum of the grating is shown in inset of Fig. 2.

The NB690 dye provided a broad fluorescence spectrum at the visible, with the light generated at the cladding of the fiber, and was successfully coupled directly into the silica core using the bending method. Thus, together with a clear Bragg peak observed, a single fiber provides an integrated light source and sensor head is demonstrated. This hybrid fiber can be used for many sensing applications at visible wavelengths, with low cost analyzing equipments.

4. Conclusions

A hybrid fiber with silica core and dye-doped polymer cladding is proposed and fabricated. The fiber design combined the advantages found in organic dyes to act as light source, and in silica fiber as an optical waveguide and grating host. The potential for the fiber to act as a combined intrinsic light source and FBG sensor is successfully demonstrated.

5. References

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